

## SPACE TRANSPORTATION STRUCTURES AND MATERIALS WORKSHOP

Solid Propulsion Integrity Program (SPIP)  
for  
Verifiable Enhanced Solid Rocket Motor Reliability

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**Goal:**

To increase the success rate of U. S. built Solid Rocket Motors (SRM).

**Recommendations:**

Increase SPIP funding from \$10.0 M/year to \$20.0 M/year. Develop a Liquid Propulsion Integrity Program (LPIP) of similar nature and funding level.

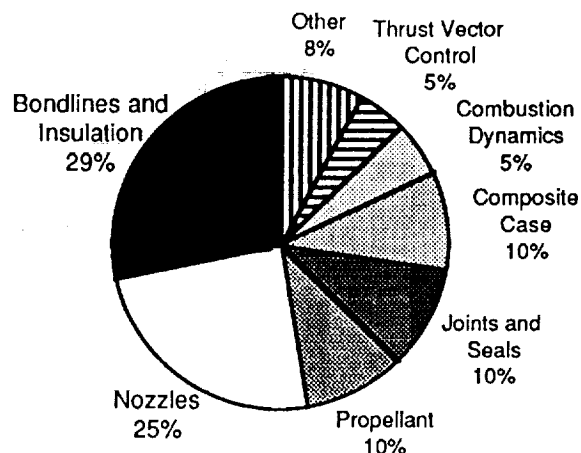
**Benefit:**

Solid & Liquid rocket engines of today have nearly equal reliabilities of 98%. Solid rockets have system advantages at liftoff due to high thrust. Liquid rockets have system advantages later in flight. Access to space costs an average of \$318M per NASA launch. NASA has 89 launches scheduled over the next five years. The loss of two launches would cost NASA \$636M. The combined SPIP and LPIP would cost NASA only \$200M and could eliminate lost launches.

**Approach:**

Set common reliability goals for Nozzles, Cases, Bondline, Propellant, and Insulation. Build a common engineering data base to support standard industry-wide reliability assessment models. Structure or enhance existing Industry/Government/User team to develop the tools, methods needed, and the data to support them. Areas where unreliabilities are found must be improved (See figure).

**Solid Rocket Motor Failures Highlight Need For Improved Reliability**

**Supporting Data:**

Solid Rocket Motor Nozzles, Cases, Bondlines, Propellant, and Insulation lack the basic engineering understanding needed to assess their true margins of safety. The key technology requirements offering the potential to significantly reduce overall systems cost, improve reliability and performance of solid rocket motors are common across all subsystems:

- Understanding and control of material and process variability.
- Analytically-driven test methodology development and improved constitutive models.
- Establishment of improved failure criteria.

\* Dr. Butler was unable to attend the conference, but as Program Manager of the NASA SPIP Bondline Program, was asked to review the conference material and present his views on what needs to be done to enhance SRM reliability.

- Understanding effects of defects.
- Design for inspectability.
- Environmentally driven process and technology development.

Specific enhancements needed in each area, in priority order, are given below.

#### **Solid Propulsion:**

1. A national data base to support a unified reliability method is badly needed for all component areas, i.e., Nozzles, Bondlines, etc.

#### **Nozzles:**

1. The areas of nozzle processing and inspection verification are severely underfunded. Hence, they are unable to emphasize design methods and process controls needed to increase permeability which would greatly reduce nozzle erosion.
2. Pore pressure enhanced models for nozzle thermomechanical and erosion response must be completed and validated. Pore pressure causes the surface to blow off during firing, increasing the threat of erosion by 100%.
3. Modeling for analysis and defect acceptance must be validated. The efforts to measure the impact of defects on nozzle margins must be known to assess reliability. Validation tests must be done.

#### **Cases:**

1. Design and testing of high reliability cases and seals for both steel and composite materials are needed. Joints are a weak link in the process. The underpinnings of joints and seals must be added to the data base for all SRM manufacturers to use in reliability analysis.
2. A case and joint instrumentation program is needed. This will allow pressurization stresses and strains to be verified and error signal generated.
3. A case contamination tolerant processing initiative must be undertaken to eliminate environmentally unsafe solvents and cleaning steps. Reusable corrosion and contamination resistant cases will reduce cost.

#### **Bondlines:**

1. Inspection methodologies for layer thickness and contaminants must be validated. Detailed testing for effects of liner thickness variation on bondline strength must be done as well as bondline strength versus detected contamination level must be verified. This is required for early introduction of X-ray Fluorescence (XRF) thickness gaging and Ultraviolet Fluorescence Contamination (UFC) inspection into production motors.
2. Defect acceptance based on unified test data needs to be enhanced. The methods and data needed to correlate real defects with bondline strength and fracture toughness are not being developed fast enough to help ASRM and NLS.
3. Design methodology, aging methods, and defect acceptance models are inadequate. An extensive test program is needed to obtain the data to validate motor health at launch time.

#### **Propellants:**

1. Relationship between constituent propellant properties and cooldown stress is not being determined and is essential. Propellant mechanical property variability affects bondline stress and propellant strength. Data show a 25% variation in properties from sample to sample. This occurrence must be understood.
2. Biaxial PBAN data are available for RSRM evaluations. Biaxial HTPB data must be taken to validate models. HTPB is the propellant for the Advanced Solid Rocket Motor (ASRM) and National Launch System (NLS) and must be measured and evaluated.

#### **Insulation:**

1. Insulators which provide both insulation and lining functions are needed. Fewer layers means fewer process steps and higher reliability.
2. Anisotropic modeling of non-asbestos fiber filled insulation is needed. Insulation anisotropic affects debond fracture location and direction.
3. Design methods and data for validating insulation optimization are needed. The current tools do not allow insulation anisotropic properties and thickness to influence bondline stresses, and they are a significant factor.